Water

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WATER WELL CONSTRUCTION PILOT PROJECT

THE CANADA – PRINCE EDWARD ISLAND
WATER MANAGEMENT AGREEMENT

Environment Canada Environnement Canada

Prince Edward Island
Department of the Environment

WATER WELL CONSTRUCTION PILOT PROJECT

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Acknowledgments

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WATER WELL CONSTRUCTION PILOT PROJECT

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1. Introduction

The Water Well Construction Pilot Project was one of several initiatives undertaken as part of the groundwater component of the Canada - P.E.I. Water Management Agreement. "The general objectives of this sub-agreement are to carry out studies to evaluate existing water use, demands and constraints, demonstrate means of increasing water's sustainable contribution to economic development in Prince Edward Island and identify future development potentials in our three water resource bases - groundwater, surface water and estuaries."

The groundwater component of these efforts involved the evaluation of baseline groundwater resources in a number of Island communities, the evaluation of the extent of pesticides in groundwater and the evaluation of new well construction techniques for the prevention of well contamination.

This report documents the findings of studies centered around the improvement of well construction and completion techniques on the Island.

1.1 Background

Prince Edward Island is unique in Canada in that virtually all potable water supplies on the Island depend on groundwater as a source of water. In addition, approximately two thirds of Islanders depend on on - site water supplies (ie. individual, private wells) for their source of supply. As a consequence of this reliance on private wells, the majority of water supplies have no protection (ie: well field protection measures), except through proper location, construction and completion of the wells themselves. Added to this, most areas serviced by on - site water supplies area also serviced by on - site sewage disposal. In more rural areas, additional sources of potential contaminants such as bacteria, nitrates and agricultural chemicals may be found in relatively close proximity to domestic wells.

The province is blessed with an abundance of groundwater, of generally excellent natural quality. At the same time, because of the nature of the aquifer materials, and the shallow depths of most domestic wells, contamination of water supplies particularly by bacteria from surface or near surface sources is a frequent problem. By way of example, in 1988 and 1989 roughly four times as many groundwater samples were collected for bacterial analysis as for chemical analysis.

In the past, the most frequent response to persistent water quality problems had been to drill a new well and abandon the old "contaminated" well, without any significant improvement in well construction, or properly addressing the source of the problem. With the technology available today, this no longer a cost effective or acceptable manner of addressing the problem. Construction of wells according to more advanced standards should significantly reduce the incidence for contamination of water supplies. At the same time in many areas, the availability of land, particularly in established areas, makes the option of simply replacing a contaminated

well unfeasible. Furthermore, unless the contaminated well is properly abandoned, it provides a pathway for contaminants to reach other portions of the aquifer and may threaten to spread the problem to wells not originally affected.

1.2 Project Objectives

The overall objectives of this initiative were to foster an awareness of the benefits to be gained from improved well construction and completion techniques, as well as evaluating the effectiveness of these techniques and their overall impact on water quality. It also was hoped that improved public awareness of the nature and sensitivity of our groundwater resources would be stimulated by the activities of the program, in concert with other activities undertaken as part of the Water Management Agreement.

As has been noted above, contamination of water supplies, particularly by the presence of bacteria from surface and near surface sources, constitutes the most frequent water quality problem on the Island. In the majority of cases, the problem can be traced to poorly constructed or maintained wells, which allow access of surface run-off, or poor quality near surface water into the well. Figure 1 illustrates some of the more common pathways by which contaminated surface water may enter a well.

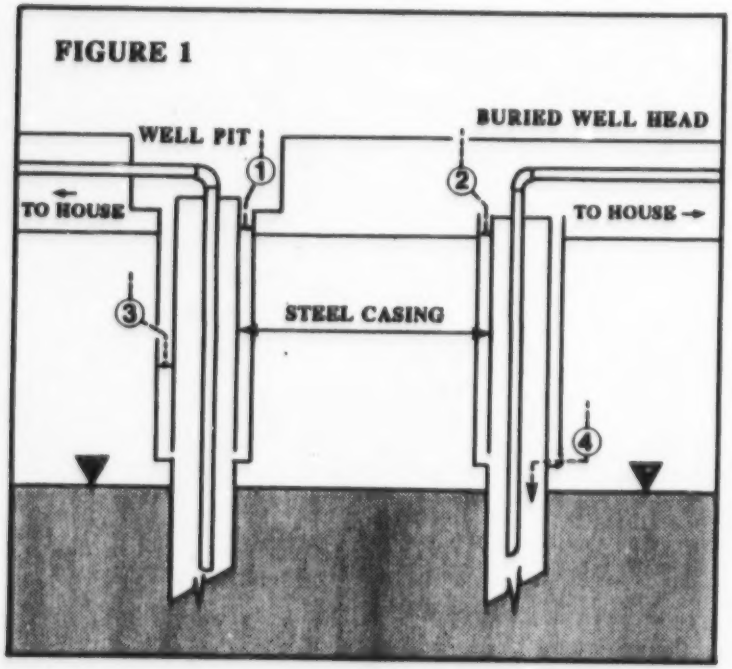
The prime objective of the project therefore, is to encourage well construction and completion practices which will effectively seal the well from these sources of contamination. The major thrust of this effort has been targeted at two changes to traditional well construction practices; the use of pitless adapters as the connection between wells and the point of use, and the sealing of casing in the surface hole with bentonite.

The first change involves the use of pitless adapters in well completion. In the past many wells were completed by placing a well seal on the top of the casing, through which the discharge pipe (and electrical cable if a submersible pump was used) would run, and then to bury the top of the well below the frost level (see the right hand side of Figure 1). Not only did this make it difficult to gain access to the well for maintenance or repair, but surface water had relatively easy access to the well through the well seal, particularly in areas of seasonally high water tables. The partial vacuum produced by the drawdown of water in the well during pumping would aid water outside the casing exploit any openings in the seal.

In other cases, wells were completed in well pits (left hand side of Figure 1). While these pits are supposed to be constructed so as to be watertight, experience has shown that many of these pits do in fact flood, again providing access of surface water to the well.

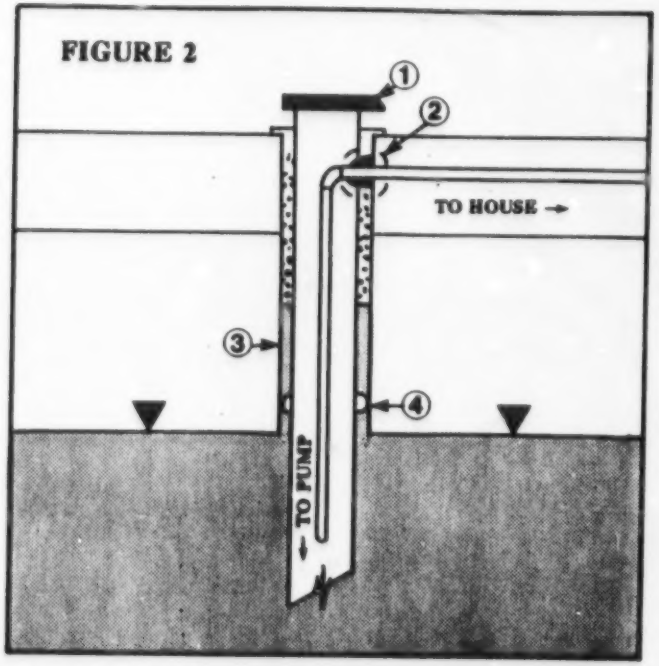
The use of a pitless adapter which allows the transmission of water (and electrical power if necessary) between the dwelling and the well, with out providing any subsurface openings in the well can eliminate these problems. Well casing extends above the ground surface and is

FIGURE 1



1. Contaminants enter well through a flooded well pit;
2. Contaminants enter well through the top of buried well casing;
3. Contaminants enter well along the annular space around the casing;
4. Contaminants enter the well below the casing.

FIGURE 2



1. Vented well cap prevents foreign matter from entering well and allows entry and escape of air;
2. Pitless adapter allows pump discharge pipe to be buried below frost level,while permitting casing to extend above ground surface;
3. Bentonite seal,a natural clay substance which expands when exposed to water,prevents the movement of the surface water along the annular space around the casing;
4. Centralizer ensures casing is properly centered in the well.

fitted with a proper sanitary well cap. As an added benefit, the installation of a pitless adapter facilitates access to the well for maintenance or repair purposes. Figure 2 illustrates a typical installation of a pitless adapter.

The second change involves introducing the practice of grouting well casing in the surface hole to prevent vertical migration of water along the annular space between the casing and the well bore, and subsequently into the open portion of the well.

In the past, most drillers in the province have relied on the natural rock or soil characteristics to seal well casing in the ground. Surface holes were generally drilled only to a diameter sufficient to allow placement of the casing, and then usually (although not always) the annular space would be back filled with drill cuttings or other native materials. Particularly in areas where there was a significant amount of claystone in the strata, wells were cased into the clay, with the hopes that the natural tendency of the clay to close in around the casing would provide an adequate seal. Obviously in areas where such claystone horizons did not occur at convenient depths, the back fill material provided the only protection against vertical movement of water along the casing.

Because surface holes were drilled to a diameter sufficient only to seat the casing, the likelihood of back fill material bridging in the annular space was relatively high. (Bridging is where the backfill material "clogs" the annular space above the area to be filled and leaves void spaces in the annulus.) At the same time this incompletely filled annular space would be more than adequate to allow a pathway for surface water along the casing to the open portion of the well below.

The usual manner in which this vertical migration of fluid along the well casing is prevented is to "grout" the annular space between the casing and the well bore with some impervious material such as cement or "puddled clay". More recently, the use of bentonite has become common for grouting applications in the water well industry. Bentonite is a natural clay material which tends to swell when it is wet. Because of this swelling action and its very low permeability it is ideal for the sealing of the annular space between the casing and the well bore, provided of course, that this grout is properly installed. As with the use of native back filling materials, the effectiveness of the seal depends as much on the method in which it is installed as the physical nature of the materials themselves. The development and evaluation of grouting methods was a primary aspect of this work.

1.3 Project Structure

The main vehicle for the project was a program whereby individual domestic wells were constructed according to specifications set out by the Department of the Environment, utilizing bentonite grouting materials to seal the well casing, and pitless adapters during well completion. Inducements were offered to home owners and drillers to participate in the program. The

program was publicized through the production of a brochure describing the program and its purpose, and through news releases. Site visits during well construction were made to assess grouting methods, and a sampling program initiated to follow up on the effectiveness of these well construction practices in reducing the incidence of contamination.

2. Project Methodology

To achieve the goals of improved well construction and completion techniques on the Island, two obstacles had to be overcome. First it was necessary to educate the public to understand and recognize the importance of well construction and to show how improved well construction could be of benefit to them. Secondly, while most drillers were aware of bentonite grouting materials and the general principles behind the grouting of wells, many did not have a significant amount of "hands-on experience", particularly in various grouting techniques. Furthermore, many drillers were skeptical about the need for, or benefits from proper grouting practices.

Another important aspect of the project was an evaluation of the overall effectiveness of these improved well construction techniques, as well as an evaluation of specific materials and methods of installing bentonite seals around well casing. In evaluating various grouting methods, the practicality and flexibility of the method was also considered. Because of deferences in the capability of different drilling equipment, it was important to identify grouting methods which would be applicable to different drilling methods and formation conditions.

2.1 Public Education

Public education on well construction practices was achieved primarily through the production of a brochure, outlining the common causes of well contamination, the purpose of the program and how to participate in the program. The brochures were distributed through regional government service centres, well drillers, and by the Building Services Division of the Department of Community and Cultural affairs, to people making applications for building permits. In addition news releases announcing the program and explaining its purpose were placed in local newspapers. A copy of the brochure is attached to this report as appendix I.

To help encourage public participation in the program, home owners were given a $40.00 credit towards the purchase of a pitless adapter, and all the necessary materials (over and above those used in traditional well construction) were supplied to the driller at no charge. The cost of a well constructed under the program would therefor be the same as, or only marginally greater than a well constructed by traditional methods.

2.2 Driller Education / Participation

Most drillers in the province had some familiarity with bentonite materials of some kind, and were at least familiar with the notion of grouting wells. Few drillers however, had extensive hands on experience in grouting wells. In addition many drillers were of the opinion that grouting of wells, under the formation conditions usually encountered on Prince Edward Island, was not generally necessary.

At the initiation of the project, a meeting was held with the well drillers, to explain the purpose of the program, provide technical details of the grouting methods to be tried, and to elicit feedback regarding technical aspects of the program. Subsequent to the meeting, the drillers were recontacted to determine what grouting methods each driller was interested in and technical details were sent to each driller outlining the methods they had indicated they would be interested in trying . Approximately half way through the project a second meeting was held with the well drillers to discuss the progress of the project.

As an incentive, the well drillers were offered a $20.00 fee for each well completed under the program, as well as being supplied with all the necessary materials for the well grouting operations.

As the program was initially set up, the driller was to notify the Department two days in advance of proceeding with a well under the program, so that department staff could be available to supervise installation of the grout. While this procedure was followed initially, it soon proved to be impractical, because of difficulty in predicting drilling schedules in advance. Department staff were on site to supervise any new grouting methods, until procedures for the method were well established, as well as for wells constructed by drillers not familiar with the specific technique.

A standard form was produced on which the details of the grouting operations were recorded including the materials used and other basic well construction details. No separate well logs were recorded, as these are required to be submitted to the Department in any event.

A total of 62 wells were completed under the program, and three of the seven drilling companies on the Island participated in the program. Two other drilling contractors have been exposed to some of the grouting techniques, through grouting demonstrations and contracts where grouting of wells was required.

3. Selection of Grouting Methods and Materials

At the project's inception, a consultant was engaged to review the available literature on well grouting, and to select a number of appropriate methods for adoption under this program on Prince Edward Island. In addition the consultant designed a work plan which would outline the basic form of the program.

After a review of the available information, six grouting methods were selected to be included under the program, and technical details of each methods and the materials required were documented. These methods and material requirements are outlined briefly in the following section of this report.

Initially the grouting materials ordered included coarse bentonite chips (1/2 to 3/4 " diameter), bentonite in pelletized form, and bentonite grout with inhibitor. The coarse bentonite chips were found to be unsuitable for the intended purpose, and were exchanged for a quantity of finer, granular bentonite. In addition a quantity of drillable plugs, casing centralizers and drive shoes were acquired.

4. Description of Grouting Methods

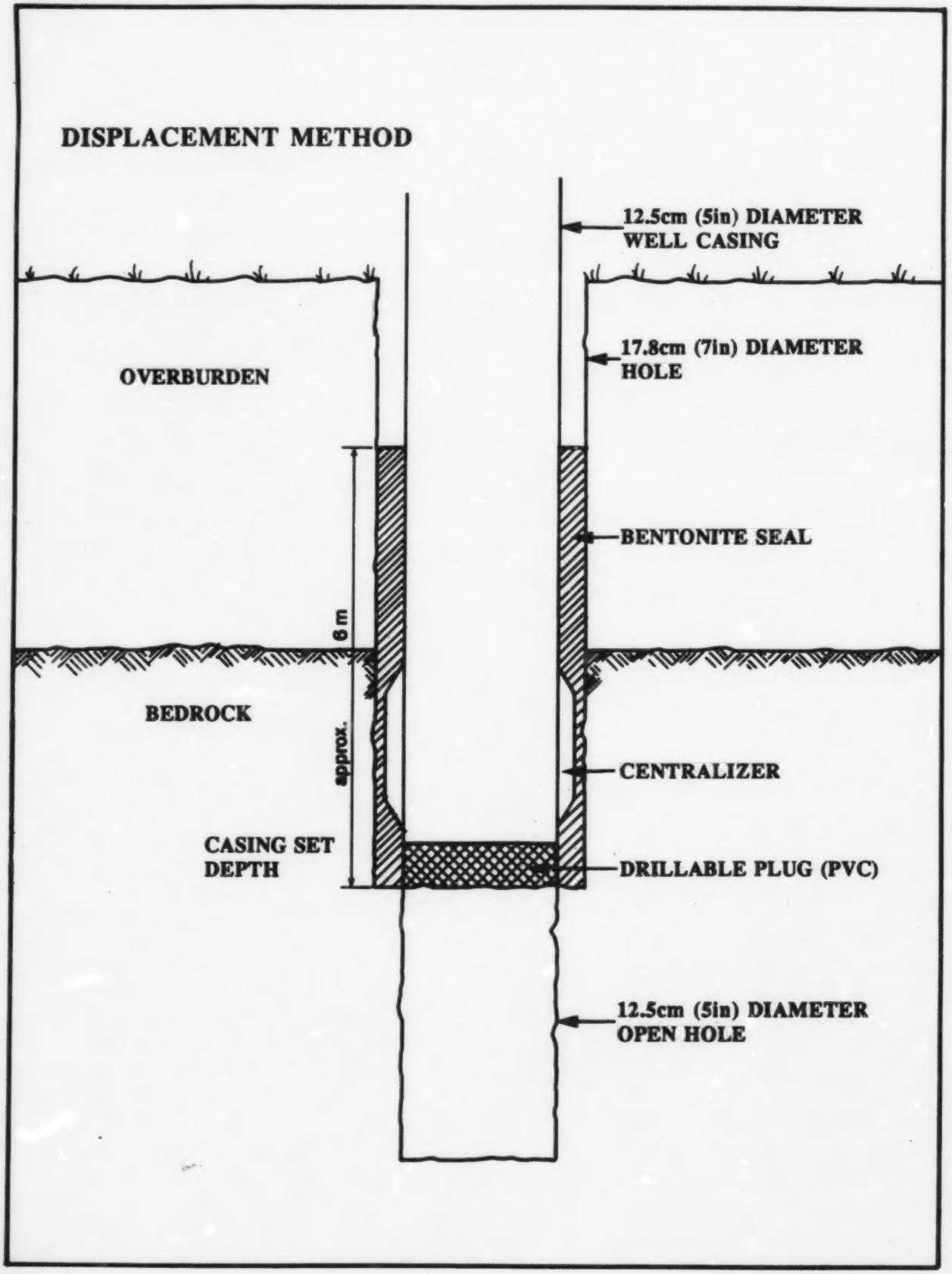
A brief description of the various grouting methods selected for inclusion in this project, is presented here, as well as comments specific to individual methods, where appropriate. In each case it was attempted to provide a seal which occupied the lower ten to fifteen feet of the annular space from the bottom of the casing, up.

4.1 Positive Displacement Method

The positive displacement method involves the squeezing of bentonite up around the casing as it is placed in the surface hole to form a seal between the well bore and the casing. After a surface hole has been drilled to the casing set depth, a sufficient quantity of bentonite is placed in the hole, and the lower end of the casing is fitted with a drillable plug. As the casing is lowered into the hole, the bentonite is squeezed up between the casing and the well bore, providing a water tight seal in the lower part of the annular space. After the casing is set the plug is drilled out and drilling of the open hole part of the well begins. Figure 3 depicts the main details of this method of grouting.

The amount of bentonite to be used was determined by calculating the theoretical volume of the annular space, and assuming that each fifty pound bag of bentonite would occupy approximately one cubic foot of space. The drillable plugs are partially hollow PVC discs, which can be tapped gently in to the bottom of the casing.

Figure 3


DISPLACEMENT METHOD
12.5cm (5in) DIAMETER
WELL CASING
17.8cm (7in) DIAMETER
HOLE
OVERBURDEN
BENTONITE SEAL
6 m
BEDROCK
approx.
CENTRALIZER
CASING SET
DEPTH
DRILLABLE PLUG (PVC)
12.5cm (5in) DIAMETER
OPEN HOLE

This method is relatively simple to use and requires no special equipment besides the drillable plug. It was one of the most frequently used methods of grouting used under the program.

The prime difficulty encountered with this method was premature failure of the drillable plugs. Frequently in the early attempts with this method, the drillable plug would fail before the casing had lowered to its final depth. As a consequence the length of the seal was not as great as initially planned, and a considerable amount of bentonite was wasted. In addition the driller then had to drill through several feet of bentonite, which is a time consuming process.

It appears that two factors contributed to this problem. First, experimentation showed that if the bentonite was allowed to sit in the hole for a period of about 1/2 hour prior to lowering the casing in the hole, fewer problems were encountered. It was also important that a sufficient quantity of water was present in the hole, (either naturally or added by the driller if necessary). Secondly it was found that it was important to introduce the bentonite into the hole slowly (two to three minutes per fifty pound bag), to promote thorough wetting and hydration of the material. With these conditions met the bentonite obtained a better consistency prior to introduction of the casing. It should be noted also that some of the plug failures occurred when the coarser bentonite chips were being used. The large diameter of these chips would inhibit complete wetting of the material and contribute to failure of the plugs.

A second factor contributing to the failure of the plugs is probably related to surface hole diameter. In nearly all occasions when department staff witnessed failure of a plug, the casing had to be driven. If the surface hole was of adequate diameter and true, little additional force would have been needed to seat the casing. It is speculated, that in these cases, there simply was not sufficient annular space to accept the bentonite. As downward pressure on the casing was increased, pressure against the plug increased until it failed.

A new design for the plugs was produced and four prototypes fabricated. The new design incorporated a conical tip which should better withstand the pressures developed while setting the casing. These plugs were not used however because of concerns relating to the materials from which they were made. Unlike the fairly rigid PVC plugs, these conical shaped plugs were made from a more flexible plastic, and it was expected that they would be too difficult to drill through after the casing is set.

Once the limitations of hole diameter and set up time for the bentonite were recognized, few problems were experienced. While all holes grouted by this method were constructed by cable tool, it is likely that with sufficient hole diameter this method could also be used by a rotary rig as well, as the weight of the casing should be sufficient to allow the casing to settle to the bottom of the surface hole.

Initially, bolt-on, stainless steel centralizers were used to ensure that the casing was properly centered in the hole. These were later abandoned as they were not robust enough to withstand even modest amounts of lateral pressure as the casing was lowered in the hole. It is likely that they would be effective if a larger hole diameter was used, but this would involve considerably more cost.

An alternate centralizer, fabricated form angle iron was used on a few casing installations. These were welded on the side of the casing a few feet from the casing bottom. These were also abandoned because they had a tendency to get "hung up" in the hole. In addition these would make pulling the casing at a later date virtually impossible.

A redesign of this latter type of centralizer might overcome these problems, or conversely, the drilling of larger diameter surface holes would be required. For the duration of the program, no attempt was made to resolve this problem, and centralizers were only used on a few wells, usually ones where a large diameter surface hole was called for by the grouting method in the first place.

4.2 Surge Tool Displacement Method

The surge tool displacement method is somewhat similar to the positive displacement method, in that bentonite is squeezed up the annular space between the casing and the well bore by pressure. The method requires the construction of a special surge tool or block, and can only be used with a rotary drill rig. Regrettably, no attempt was made to try this method.

Briefly the method involves drilling a surface hole to the casing set depth, and suspending the casing approximately one foot off the bottom of the hole. The desired quantity of bentonite is placed in the casing, with additional water if the hole is dry, and the bentonite allowed to set for approximately 15 minutes. Following this the bentonite is forced down and out of the casing and up into the annular space by a surge block attached to the drill string. Once the grout has been forced out, the casing is lowered to the bottom of the hole and driven a short distance into bedrock. Figure 4 illustrates the basic aspects of this method of grouting.

As noted above the main drawback of this method is the fact that it requires positive pressure on the drill string to force the surge tool down the casing, thus the operation cannot be performed with a cable tool rig.

4.3 Bentonite Grout Method

The bentonite grout method is similar to many cement grouting operations where a thin slurry is pumped under pressure to the desired zone. In the grouting of wells in this program, an oversized surface hole was drilled to accommodate a tremie pipe outside the casing, and the casing was lowered into the hole, with centralizers stabilizing the casing in the centre of the hole. A

Figure 4

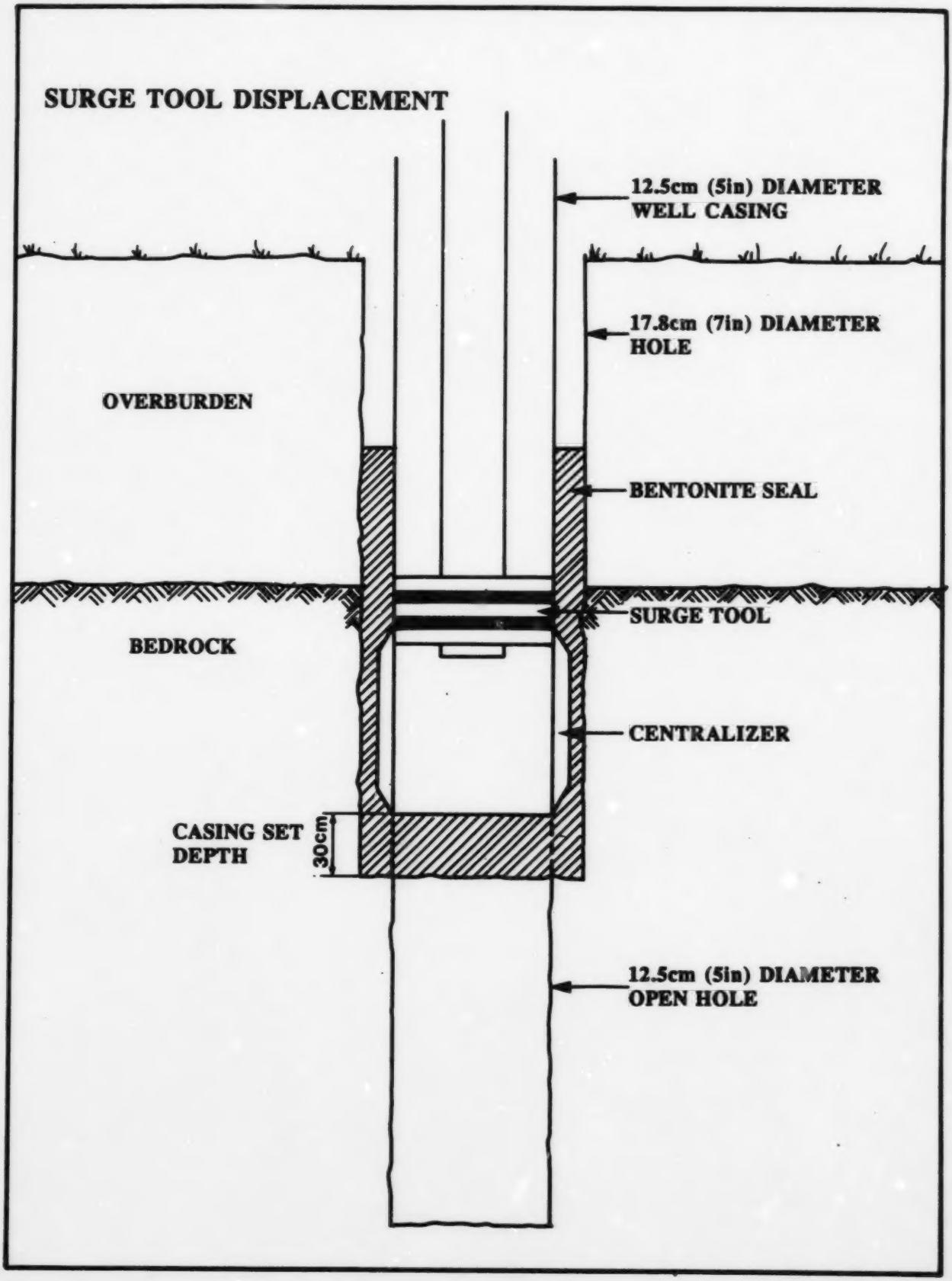
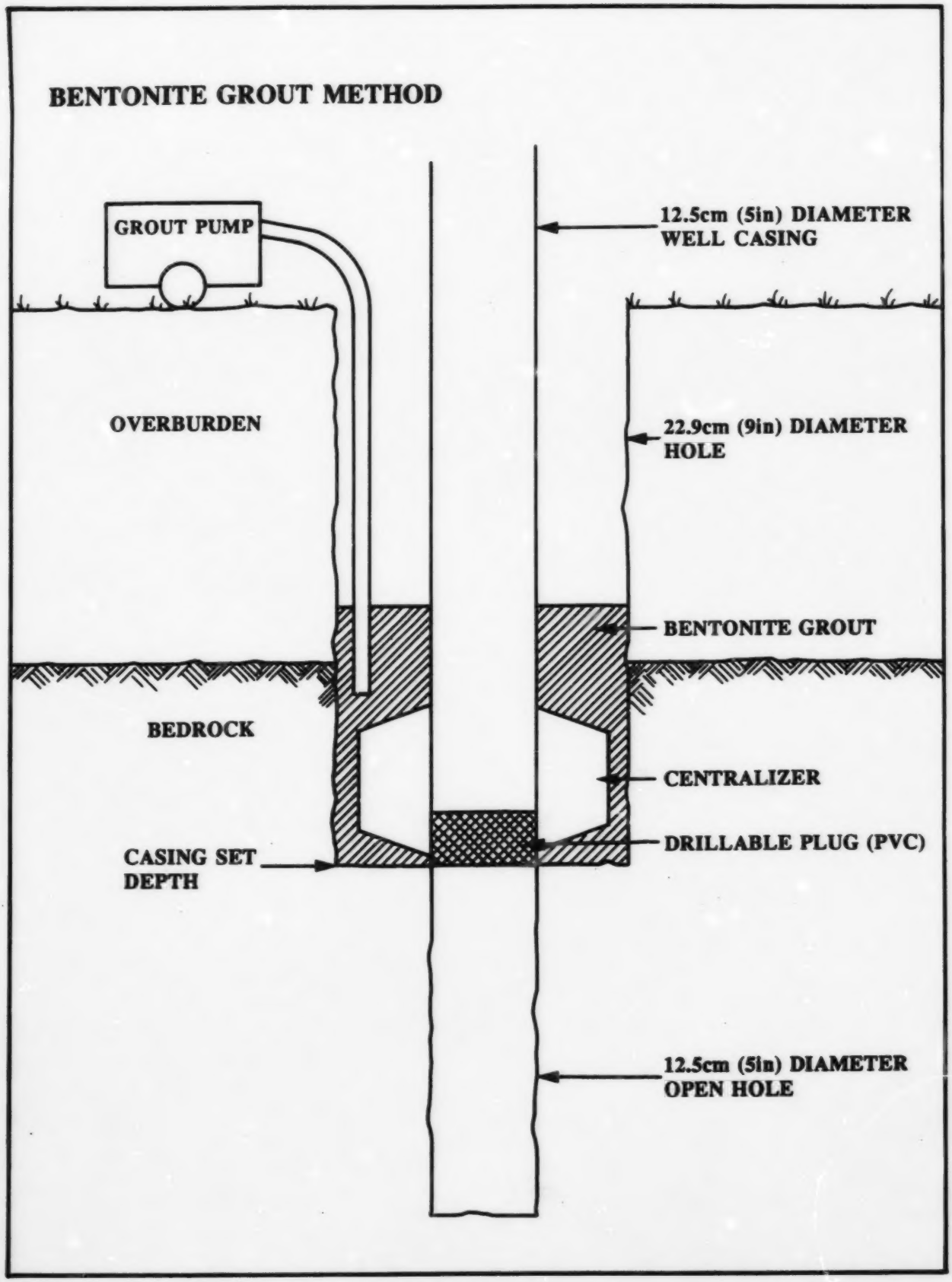

SURGE TOOL DISPLACEMENT
12.5cm (5in) DIAMETER
WELL CASING
17.8cm (7in) DIAMETER
HOLE
OVERBURDEN
BENTONITE SEAL
SURGE TOOL
BEDROCK
CENTRALIZER
CASING SET
DEPTH
30cm
12.5cm (5in) DIAMETER
OPEN HOLE

Figure 5


BENTONITE GROUT METHOD
GROUT PUMP
12.5cm (5in) DIAMETER
WELL CASING
OVERBURDEN
22.9cm (9in) DIAMETER
HOLE
BENTONITE GROUT
BEDROCK
CENTRALIZER
DRILLABLE PLUG (PVC)
CASING SET
DEPTH
12.5cm (5in) DIAMETER
OPEN HOLE

bentonite grout was mixed, according to the manufacturer's directions, and then pumped down the surface hole via a tremie pipe, starting at the bottom of the hole and working up to the desired level.

Once the grouting has been completed it is desirable to drive the casing a short distance to ensure it is well seated in the formation and the relatively thin slurry will not run out into the open hole below as drilling proceeds. It is probably advisable also to allow the grout to set for a period of time (1/2 hour) before proceeding with drilling to allow any excess water in the grout to diffuse into the formation. Figure 5 illustrates the basic construction details for wells grouted in this manner.

This method worked well under all circumstances, and may be the most effective method of sealing wells, particularly in situations where it is desired to seal the entire annular space from the bottom of the casing to ground level, since the grout does not have to be displaced up around the casing but is delivered directly to the location it is to be emplaced. Because the slurry is of a relatively thin consistency compared to the granular bentonite materials, it is expected that it is especially effective at sealing smaller pore spaces and openings in the formation. It also has the advantage that it makes no difference what type of drill rig is used to drill the hole, provided it has the ability to drill a hole of sufficient diameter.

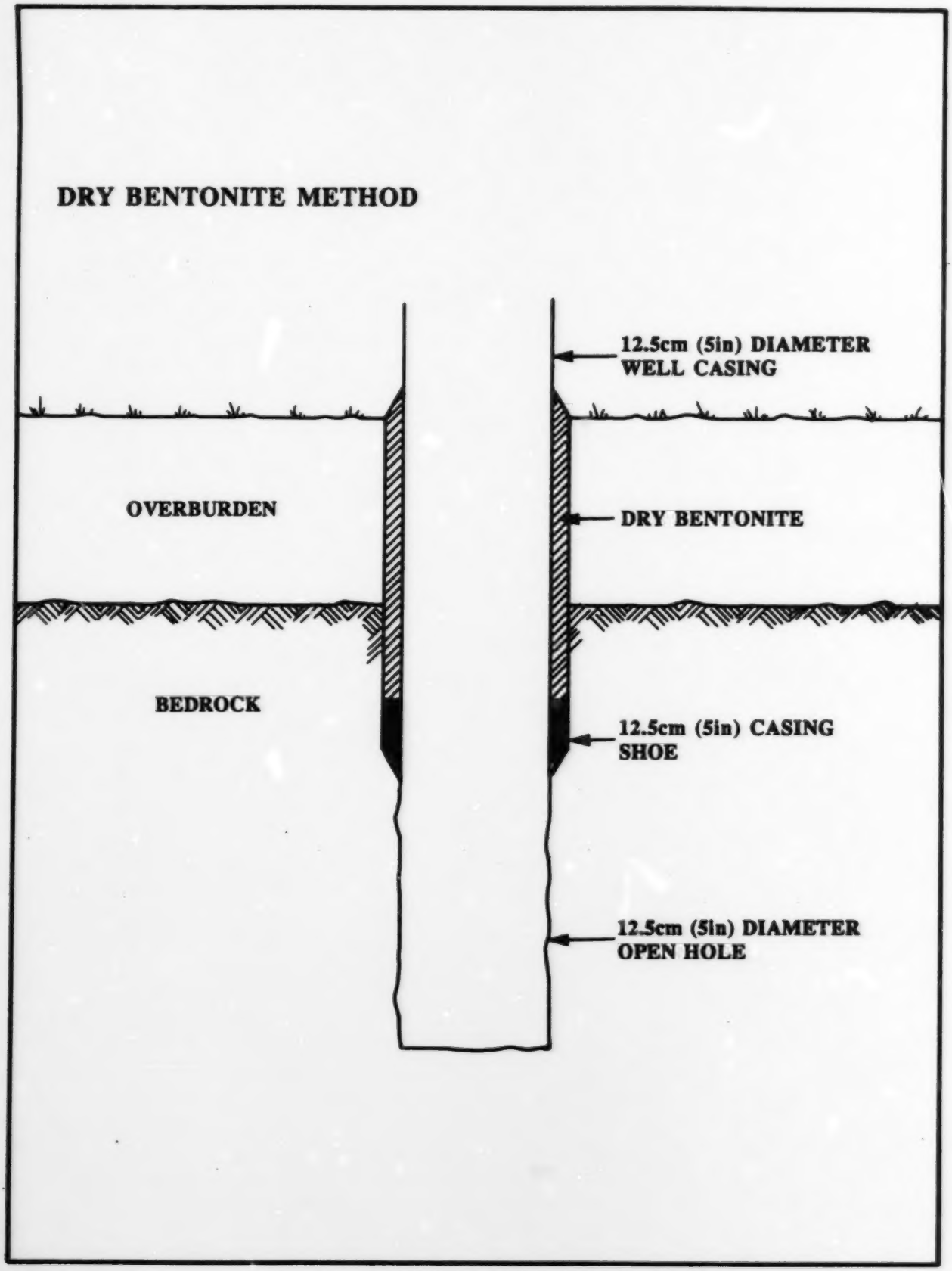
The method does have a few drawbacks however. The method is relatively time consuming, requires more training and experience to be used effectively, and it requires additional equipment not presently used by many drillers on the Island. The method also requires a relatively large diameter surface hole to accommodate both the casing and the tremie pipe. In addition the bentonite grouting compounds are more expensive than the granular bentonite used in other methods. It is likely that this method would be best suited to areas where problems of groundwater contamination are anticipated, or where there is a significant financial investment in a well (eg. a central water supply).

Experience showed that it is a good precaution to have some coarser bentonite on hand when using this method, because in zones of significant fracturing a good deal of the fine slurry will be lost. In these cases it is advisable to use some hole plug or other coarse bentonite to seal off higher permeability zones as they are encountered.

4.4 Dry Bentonite Method

In this procedure, bentonite is placed by pouring it dry along the outside of the casing as the casing is being lowered in the hole. A surface hole is first drilled to the desired casing set depth, and a drive shoe fitted to the end of the casing. The casing is then lowered into the hole, with the dry bentonite being added slowly, making sure that it settles at the same rate of the casing. Once the casing has reached the bottom of the hole, drilling proceeds, and natural soil moisture is relied on to hydrate the bentonite. Figure 6 shows the basic construction details for this method.

Figure 6


DRY BENTONITE METHOD
12.5cm (5in) DIAMETER
WELL CASING
OVERBURDEN
DRY BENTONITE
BEDROCK
12.5cm (5in) CASING
SHOE
12.5cm (5in) DIAMETER
OPEN HOLE

This method was only experimented with a few times and under less than ideal conditions. Overburden conditions were such that it was difficult maintaining an open hole. As a consequence the overburden materials had a tendency to fill in behind the casing as it was lowered, leaving little room for the bentonite. In addition it was not possible to physically measure the extent of the bentonite seal in these wells, although the rate at which the bentonite was settling relative to the advancement of the casing suggested that little of it was following the casing down the hole.

It would seem that one of the short-comings of this method is the manner in which the bentonite is kept from falling into the open hole below the casing as it is being lowered into the hole. The small shoulder or ledge where the drive shoe is attached to the casing is relied on to retain the bentonite in place. Assuming that the outer perimeter of this shoulder has to be only slightly smaller than the hole diameter in order to retain the bentonite, not much room (width of the annular space) is left in which to create an effective seal. This method is reported to be used effectively elsewhere however (R. Leonard, 1985), and it is possible that with better hole conditions the method would have promise on the Island as well.

One final possible drawback with the use of this method on the Island is a general reluctance to use drive shoes on the bottom of the casing. Arguments are made that the attachment of a drive shoe makes subsequent pulling of the casing difficult or impossible, and that because of the generally soft bedrock conditions on the Island, casing can be successfully driven without a shoe. One could counter however, that if the use of a drive shoe reduce the instances of contamination, then there would be less frequent cause to pull casing for well reconstruction in the first place.

4.5 Oversized Dry Bentonite Method

The oversized dry bentonite method was not attempted, but in most respects is similar to the method described above. It differs principally in the diameter of the surface hole, as the name would imply, and in that the bentonite is retained by a collar attached to the casing tip rather than a drive shoe. It is expected that the larger diameter hole and the larger collar as opposed to the narrow shoulder on the drive shoe might address some of the concerns outlined above regarding an adequate annular space to effectively create a seal, and the problems of the bentonite settling at the same rate as the casing during installation. Some concerns were expressed by drillers that the collar would not be effective if the surface hole was irregular.

4.6 Bentonite Pellet Method

This method was apparently designed as a type of " control method" , as it was reported to be the most common method of grouting wells in use by drillers on P.E.I. Subsequent discussion with drillers suggests that this method was not in fact used frequently. The method involves simply pouring a quantity of bentonite pellets into the open surface hole, and then seating the

Figure 7

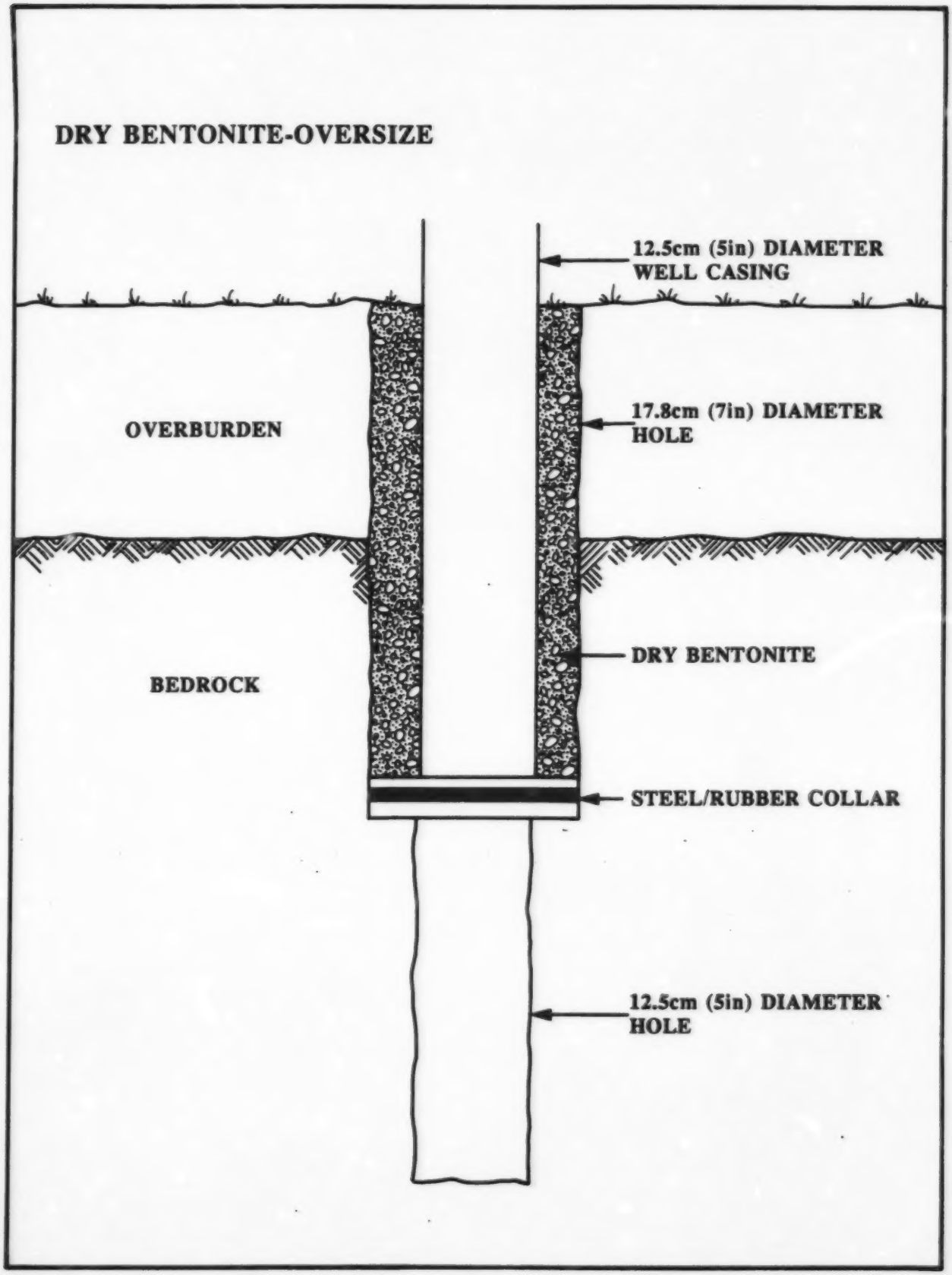
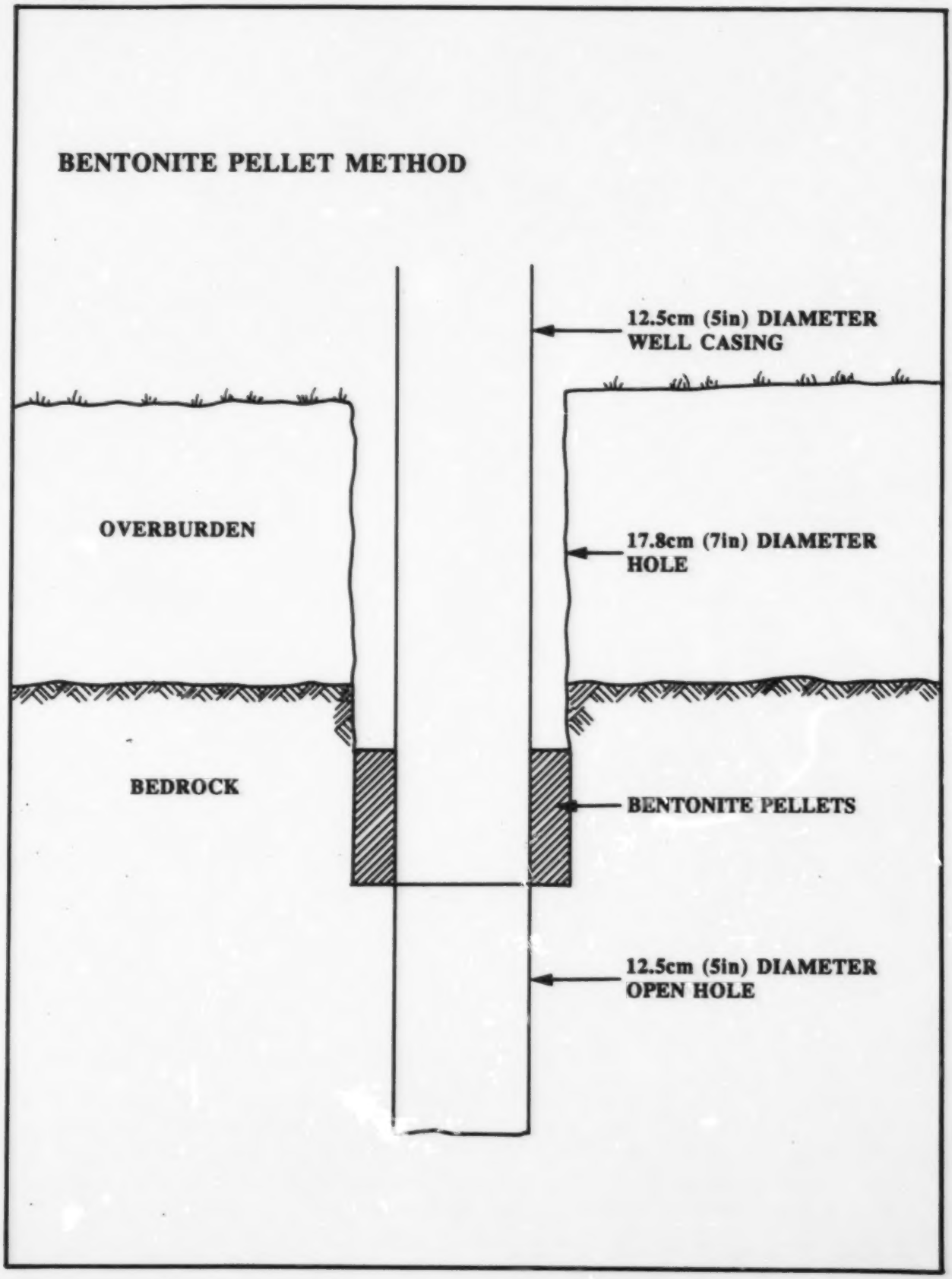

DRY BENTONITE-OVERSIZE
12.5cm (5in) DIAMETER
WELL CASING
OVERBURDEN
17.8cm (7in) DIAMETER
HOLE
BEDROCK
DRY BENTONITE
STEEL/RUBBER COLLAR
12.5cm (5in) DIAMETER
HOLE

Figure 8


BENTONITE PELLET METHOD
12.5cm (5in) DIAMETER
WELL CASING
OVERBURDEN
17.8cm (7in) DIAMETER
HOLE
BEDROCK
BENTONITE PELLETS
12.5cm (5in) DIAMETER
OPEN HOLE

casing in the hole. The bentonite in the casing is then drilled out and drilling proceeds. This method is relatively straight forward, but obviously results in the waste of a significant amount of material. In addition, although the bentonite is soft, it is time consuming to remove from the hole because it is relatively sticky, and is not easily removed with a bailer.

4.7 Alternate Methods

During the course of the program, field conditions occasionally called for modifications to the practices outlined above. In addition the well drillers were encouraged to suggest or try new ideas which might either improve the performance of the seal or result in more practical operations.

One of the practices adopted for use by rotary drill rigs involved the drilling of an oversized hole, and placing a small quantity of bentonite directly in the bottom of the hole. The casing was then set, and the remaining amount of bentonite was flushed down the annular space with generous amounts of water. The reason for the modification came primarily from concerns as to whether the rig could exert sufficient downward force on the casing using the drillable plug from the positive displacement method. While the main thrust of all the methods outlined previously was to avoid the possibility of the bentonite bridging part way down the hole, field tests showed this method to work effectively, and with a minimum of effort. At the same time it is not recommended that this method be employed for holes with more than forty feet of casing, as below this depth it becomes difficult to verify the level of bentonite in the annular space.

Some other modifications involved the use of alternate materials as drillable plugs. Attempts using sheet metal appear to have worked successfully, although there is the possibility that any sharp edges on materials accidentally left in the hole could cause problems for electrical wires or plastic piping subsequently installed in the well.

Other alterations to the practices outlined above included a pre-wetting of the granular bentonite prior to introducing it in the hole, to ensure that it was fully hydrated, and thus as pliable as possible. This practice may be of particular use in the application of the positive displacement method.

5. Evaluation of Grouting Techniques

As important as demonstrating well grouting techniques is the evaluation of these techniques. This evaluation includes an assessment of individual grouting methods as well as an assessment of the effectiveness of improved well construction practices in general in reducing the incidence of well contamination. The former has been attempted primarily through field evaluations at the time of grout installation. The issue of improvements in water quality as a result of

improved well construction methods has been addressed through a bacteriological sampling program involving wells constructed under the program, and comparison with a data base compiled of bacteriological samples collected during routine Department activities.

5.1 Field Evaluations

The most basic evaluation undertaken for this project involved field supervision of the grouting activities, and physical checking of the position of the bentonite in the annular space. It was decided that for most domestic applications an acceptable seal would be created by filling the lower 10 - 15 feet of annular space with bentonite. To check this it was necessary only to know the unit volume of the annular space (ie. cubic ft. per ft. of casing), the volume of the grout emplaced , and calculate the length of annular space that the grout should theoretically fill.

A weighted line was then used to sound the annular space to determine the actual length of annular space filled. If the bentonite had bridged, then the actual or measured height of bentonite in the annulus would be greater than the calculated height. Naturally some allowances had to be made for irregularity of the hole, and the swelling action of the bentonite. Laboratory trials, conducted with the same materials in clear plastic pipe, suggested that swelling of the hydrated bentonite would not significantly change the volume of the grout under the confined conditions expected in the annulus.

A total of 16 well installations were supervised by department staff, constituting 25% of the wells completed under the program. In most cases the level of bentonite measured in the annular space corresponded well with the predicted level, considering the factors noted above regarding expansion of the bentonite and hole irregularities. When departures from the expected levels were noted , these were most often cases where the bentonite did not rise as high as the calculated value. These circumstances would imply that the surface hole volume was larger than the calculated volume, not that the bentonite had bridged. When a drillable plug failed prematurely, a substantially lower level of bentonite in the annulus was noted.

5.2 Sampling Program

To evaluate the overall effectiveness of improved well construction and completion practices on the Island, a sampling program was initiated, and a "control" data base compiled against which to evaluate the results of the program. Sampling and analyses were conducted according to the same protocol used by the Department of the Environment's Community Services Lab for total coliform bacteria.

Sampling of wells completed under of the program was conducted during the period of June, July and August of 1989, and January, February and March in 1990. 52 wells were sampled, with the 10 remaining wells being unavailable for sampling due to various circumstances.

The control population or sample is based on samples collected for mortgage certificates, over the period of March 1988 to March 1990. A total of 1778 samples are represented in the data base. The mortgage certificate data base was chosen so as to eliminate, to the extent possible, any bias in the control sample. A data base composed of all bacterial analyses conducted by the department would be expected to be biased significantly towards problem areas, and misrepresent average conditions on the Island.

As requests for analyses for mortgage purposes are presumably motivated simply by the desire to sell or buy a property, they should represent a relatively random sample. When recording results of the analyses, only the first sample collected at a residence was recorded, as repeated samples at a location with water quality problems would seriously bias the data.

Because of the manner in which the results of mortgage certificate information is archived, it was difficult to devise a data base which incorporated samples only for the same time period as the sampling of the pilot project wells, for the first year of the project. These factors could become significant because weather conditions, and thus water table elevations and the amount of run-off, vary considerably throughout the year. Since there is good reason to expect a correlation between high water tables and a high frequency of bacterial contamination, this may introduce some bias into the data.

For these reasons, two separate, smaller data bases were compiled during the second year of the project which coincide with the periods in which pilot project wells were sampled. These data may provide some insight into these effects, although other factors which should also be taken into consideration are discussed below. Table 1 presents the results of the sampling program and the corresponding information from the mortgage certificate data base.

Table 1 Frequency of bacterial counts (total coliform)

Time Period	Mortgage Certificate	Pilot Project
Mar. 88 - Mar. 89	19.6%	N/A
Mar. 89 - Aug. 89	12.3%	8.00%
Sep. 89 - Mar. 90	10.2%	7.69%
Total 88 - 90	14.5%	7.75%

The sampling program included a total of 52 wells, of which 4 wells (7.5%) had small total coliform counts (maximum count of 4 organisms / 100 ml). It is probably worth noting that one of these four wells was improperly completed, with the top of the well being buried in a low lying area prone to run-off.

In comparison, the mortgage certificate data base with the total of 1778 analyses had 257 results with bacteria counts (14.5%) and 35% of these had coliform counts over 10 (the recommended limit for human consumption according to the Canadian Guidelines for Drinking Water Quality, Health & Welfare Canada).

Thus on an overall basis, it would appear that more up to date well construction practices may be expected to reduce the incidence of bacterial contamination by almost 50%. It is also worth noting that while in no case were the bacteria counts in pilot project wells, greater than 10, 35 % of the control wells had bacteria positives in excess of this value, with some results reaching in excess of 2400 organisms per 100 ml.

In addition to these overall results, there are some other features which can be noted in the data. It was commented earlier that there may be some temporal variation in the data, as a result of different physical (meteorological) conditions during sampling periods, or other factors. One of the more interesting trends noted was a general decline in the incidence of bacterial contamination for samples represented in the data base over the two year period in general. Mortgage certificate samples collected between the spring of 1988 and the spring of 1989 showed a frequency of contamination of 19.6%. Samples collected in the spring and summer of 1989 averaged a contamination rate of 12.3 % and samples collected through the fall and winter of 1898 - 1990 showed a frequency of contamination of only 10.2%.

These data appear to show an apparent progressive improvement of water quality over time, as well as possibly showing some indication of the magnitude of seasonal effects on water quality by comparison of spring and summer samples with fall and winter samples form 1989 -1990. By way of comparison, of 652 samples collected in 1980 for bacterial analysis, 27% were found to have bacteria counts. With this latter data however, no breakdown between mortgage samples and other sampling activity is readily available, and the sample data may be significantly biased towards problem wells.

It should also be noted that the sample of wells constructed under the pilot project are probably not without bias. As well drillers only constructed a relatively small number of wells under the program relative to their overall business, it is not unlikely that the wells they selected for inclusion were those in locations where water quality problems were anticipated in the first place.

While it is difficult to distinguish between the influence of the various factors contributing to the frequency of contamination in either the pilot project wells or the control data base, it does appear that two general trends are present. First, wells constructed according to the practices utilized under the pilot project appear to experience bacterial contamination approximately half as frequently as a random sample of wells on the Island. Secondly, although only a short time span is represented by the control data base, overall water quality appears to be improved in the random sample during the two years .

This latter feature could have significant implications, although as noted above, further work on records for a longer time period would be needed to reach any firm conclusions. Nonetheless it is possible to suggest that some of this improvement could be a result of improved well construction practices on the Island in general. This interpretation of course, would be highly dependent on the number of factors such as the number of newly constructed wells represented in the data base, weather related factors etc.

6. Conclusions and Recommendations

The results of the Water Well Construction Pilot Project indicate that improved well construction and completion techniques, particularly the use of pitless adapters, and the practice of sealing the annular space between the casing and the well bore with bentonite, can play an important role in reducing the incidence of bacterial contamination of wells. A comparison of wells constructed under the program, with a random sample of bacterial analyses over the past two years suggests that the frequency of contamination may be reduced by nearly 50% as a result of these improved techniques.

While it is recognized that there is insufficient data to support any firm trends, the mortgage certificate data base suggests that the overall frequency of contamination has declined over the period of the program. If it is assumed that a significant portion of these samples were collected from new homes, then it is possible that this reflects an improvement in well construction practices in the province in general.

It is believed that considerable progress has been made in the area of increased public awareness, and more particularly in increased acceptance of newer drilling techniques by well drillers. At a meeting with well drillers in May of 1989, approximately 1 year after the program had begun, most drillers indicated that they used bentonite at least on some occasions, and some indicated that they made it a standard practice to grout wells they constructed.

Other indications of the growing acceptance of well grouting practices are shown by trends in the well drilling supply industry. One supplier indicated that shipments of bentonite had increased by approximately 100% between 1988 and 1989.

The efforts of this program have also been reflected in recent changes to legislation in the province. On April 1 1990, new water well regulations (Environmental Protection Act, Water Well Regulations, No. EC188/90) came into force which make the grouting of all wells mandatory. Experiences gained from the pilot project have played a significant role in this process, and the methods approved for grouting of wells under these regulations are based on experience gained during this program.

In addition, these regulations specify stricter requirements for well completion, and prohibit the practice of burying the top of a well below grade. All wells constructed on P.E.I. now must be completed with a pitless adapter or a water tight well pit which extends above grade by a minimum of 20 cm.

While a considerable amount of progress has been made through this project, there are still areas where more work is needed. The implementation of new water well regulations will require a considerable effort, both in terms of enforcement and continuing education.

Further work should be carried out to develop or refine additional grouting techniques, and to overcome some of the obstacles noted earlier in the report (such as grouting of casing in caving formations). The use of alternate grouting materials, and or procedures may provide a greater degree of flexibility to well drillers, while reducing the overall costs to the home owner.

At a time when pressures on groundwater resources are increasing, the results of this program indicate that a little common sense, foresight and imagination can go along way towards protecting this resource.

References:

- Guidelines for Canadian Drinking Water Quality, Health and Welfare Canada, 1989

- Leonard, R. , Dry Grout Driven Method: New Approach to Grouting, Groundwater Age, March 1985

- Laws of Prince Edward Island, No. EC188/90, Environmental Protection Act, Water Well Regulations, April 1990

APPENDIX

How Do I Qualify?

To qualify for this project each well owner must:

1. Construct a well with a minimum casing diameter of 5 inches (12.5cm).

2. Install a pitless well adaptor to connect to the building plumbing system. A copy of an invoice confirming the purchase of this item will be necessary to receive the credit.

3. Construct the well so that the top of the well casing is a minimum of 6 inches (15cm) above the ground surface after final landscaping of the surrounding area.

4. Install a vented well cap on the top of the well casing.

5. Have the well inspected by the provincial Water Resources Branch to ensure that the P.E.I. Environmental Protection Act and Regulations concerning proper well construction and completion have been followed.

How Does The Project Work?

All materials required for the installation of the bentonite seal will be supplied through the driller at no extra charge to the well owner.

Participation in this project will assist in developing new well construction techniques to improve water quality and reduce the risk of groundwater contamination.

A representative of the Department of Community & Cultural Affairs will supervise the installation of the bentonite seal and will collect a water sample for analysis after completion of the well.

Further Information?

If you have any questions about this project, please contact Water Resources Branch of the Department of Community & Cultural Affairs, 11 Kent Street, Charlottetown or phone 892-0311, and ask about the Well Construction Pilot Project.

Environment Canada
Environnement Canada

Community & Cultural Affairs

Water Well Construction

PILOT PROJECT

Water

P.E.I.'s MOST PRECIOUS RESOURCE

The Water Resources Branch of the Prince Edward Island Department of Community & Cultural Affairs and the Inland Waters Directorate of Environment Canada, with the cooperation of the P.E.I. Well Drillers Association are conducting a pilot project to improve well construction methods, and maintain the quality of the province's groundwater resources.

What is the Project?

In many cases, poor well construction techniques do not adequately protect wells from contamination, and result in poor quality water.

Over the next two years, new well construction techniques will be employed on a limited number of wells. The project offers incentives to individuals having a well constructed and to the well drillers, including:

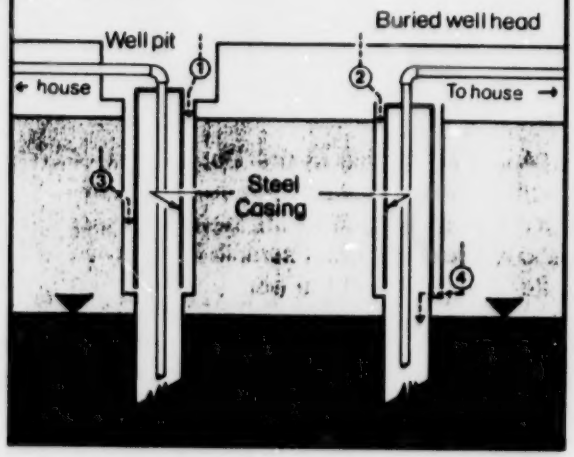
- a forty dollar credit towards the purchase of a *pitless well adaptor*;*
- one well casing *centralizer*;*
- *bentonite** to seal the well casing;
- one drillable well plug to allow proper placement of the bentonite seal;
- one litre of well disinfectant;
- compensation to the well driller for completing the extra work required.

* see diagram 2.

What Are Some Common Causes Of Well Contamination?

Often well contamination results from contaminated surface run-off entering the well.

diagram 1

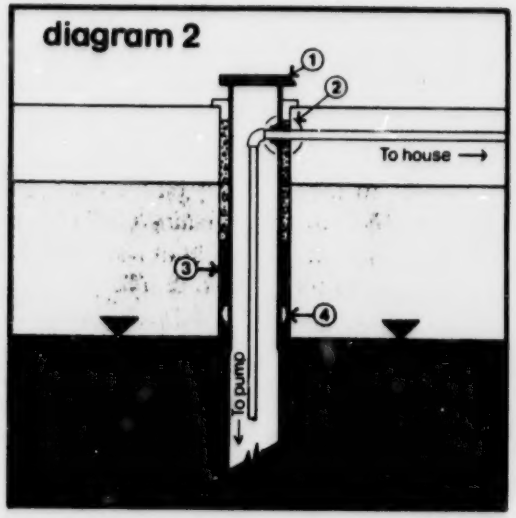


1. contaminants enter well through a flooded well pit;
2. contaminants enter well through the top of buried well casing;
3. contaminants enter well along the annular space around the casing;
4. contaminants enter the well below the casing.

How Can Better Protection Be Provided?

Better sanitary protection of the water supply can be provided by preventing downward leakage along the casing from surface sources of contamination.

diagram 2



1. vented well cap prevents foreign material from entering well and allows entry and escape of air;
2. pitless adaptor allows pump discharge pipe to be buried below frost level, while permitting casing to extend above ground surface;
3. bentonite seal, a natural clay substance which expands when exposed to water, prevents the movement of the surface water along the annular space around the casing;
4. centralizer ensures casing is properly centered in the well.